go half the distance that a tap is propagated during the interval between two taps : *half* the distance, because in going away from the source we are approaching the reflector and so make a double change—we not only get the original ones later, but we also get the reflected ones earlier, and so coincidence will have again been reached when we have gone half the distance between any pair of compressions travelling in the air. Now, if the taps succeed one another slowly, the distance in the air between any two of them travelling through it will be considerable ; any one of them will go a considerable distance from the source before its successor is started after it. If, on the contrary, they succeed one another rapidly, the distance between the travelling taps will be small. In general, if V be the velocity with which a tap travels, and T be the interval of time between successive taps, the distance apart of the taps travelling in the air will be $\lambda = VT$. By arranging, then, that the taps shall succeed one another very rapidly, *i.e.* by making T small, we can arrange that λ may be small, and that consequently the distance between our source of sound and the reflecting wall may be small too, and yet large enough to contain several places at distances of $\frac{1}{2}\lambda$ apart between the source and the reflector where the incident and reflected taps occur simultaneously. Now, a very rapid succession of taps is to us a continuous sound, and where the incident and reflected taps coincide we hear simply an increased sound, while at the intermediate places where the incident taps occur in the intervals between the reflected taps we do not hear this effect at all. In the case of a succession of sharp taps we would hear in this latter place the octave of the original note, but if the original series be, instead of taps, a simple vibration of the air into and out from the reflector, the in and out motions of the incident waves will in some places coincide with the in and out motions of the reflected wave, and then there will be an increased motion, while at intermediate places the *in* and *out* motions of the incident wave will coincide with the *out* and *in* motions of the reflected wave, and no motion, or silence, will result, so that at some places the sound will be great and at intermediate places small. This whole effect of having an incident and reflected wave travelling simultaneously along a medium can be simply and beautifully illustrated to the eye, by sending a succession of waves along a chain or heavy limp rope or an india-rubber tube fixed at the far end so as to reflect the waves back again. It will then be found that the chain divides up into a series of places where the motion is very great, called loops, separated by points where the motion is very small, called nodes. The former are the places where the incident and reflected motions reinforce, while the latter are where these motions are opposed. If we measure the distance between two nodes, we know that it is half the distance a wave travels during a single vibration of the string, and so can calculate the velocity of the wave if we know the rate of vibration of the string. This is the second method mentioned above for finding the velocity of sound. There are so many things illustrated by this vibrating chain that it may be well to dwell on it for a few moments. We can make a wave travel up it, either rapidly or slowly, by stressing it much or little. If a wave travels rapidly, we must give it a very rapid vibration if we wish to have many loops and nodes between our source and the reflector ; for the distance from node to node is half the distance a wave travels during a vibration, and if the wave goes fast the vibration must be rapid, or the distance from node to node will be too great for there to be many of them within the length of the chain. Another point to be observed is the way in which the chain moves when transmitting a single wave and when in this condition of loops and nodes, *i.e.* transmitting two sets of waves in opposite directions. There are two different motions of the parts of the chain it is worth considering separately. There is in the first place the displacement of any link up or down, and in the second place there is the rotation of a link on an axis which is at right angles to this up and down motion. Now, when waves are going up the chain those links are rotating most rapidly which are at any time most displaced : it is the links on the tops and bottoms of waves that are rotating most rapidly. On the other hand, in the case of loops and nodes the links in the middle of loops never rotate at all ; they are much displaced up and down, but they keep parallel to their original direction all the time, while it is the links at the nodes where there is no displacement up and down that rotate first in one direction and then back again : there is, in the loops and nodes condition, a separation of the most rotating and the most displaced links which does not occur in the simple wave. There is a corresponding relation between the most rotated and the most rapidly moving links. These are the same links half-way up the simple waves, but in the loops and nodes the most rapidly moving links never rotate at all, while those at the nodes that get most rotated are not displaced at all. These remarks will be seen hereafter to throw light on some of the phenomena observed in connection with Hertz's experiments : hence their importance.

It will be observed that the method of measuring the velocity at which a disturbance is propagated along a string and which depends on measuring the distance between two nodes is really only a modification of the direct method of finding out how long a disturbance takes to go from one place to another ; it is one in which we make the waves register upon themselves how long they took, and so does not require us to have at our disposal any method of sending a message from one place to another more quickly than the waves travel, and that is very important when we want to measure the rate at which disturbances travel that go as fast as light. If the wave travels very fast, we must have a very rapid vibration, unless we have a great deal of space at our disposal ; for the distance between two nodes is half the distance the wave travels during one vibration, and so will be very long if the wave travels fast, unless the time of a vibration be very short. Hence, if we wish to make experiments in this way, in a moderate-sized room, on a wave that travels very fast, we must have a very rapid vibration to start the waves.

(*To be continued.*)

METEOROLOGY OF BEN NEVIS.[1]

THIS work, just issued by the Royal Society of Edinburgh as vol. xxxiv. of its Transactions, is a quarto volume of 467 pages, giving in detail the hourly observations at the Ben Nevis Observatory from December 1883 to the close of 1887, together with a log containing much that is interesting and novel in meteorological observing ; the five daily observations made in connection therewith at Fort William, and a report by Dr. Buchan on the meteorology of Ben Nevis.

This is, it is believed, the only existing combined high and low level Observatories sufficiently near each other in horizontal distance as to be virtually one Observatory : completely placed in one of the greatest highways of storms in the world ; and at such a height as to be occasionally above the storms that sweep over that part of Europe, and frequently, as the winds show, within a geographical distribution of pressure at this height widely different from what obtains at the same time at sea-level. Further, the Observatory affords unique facilities for supplying, through its observations, those physical data which are absolutely indispensable in any discussion of the problems involving the relations of height to temperature, humidity, and pressure in the free atmosphere.

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[1] "Meteorology of Ben Nevis." By Alexander Buchan, LL.D., Secretary of the Scottish Meteorological Society. Transactions of the Royal Society of Edinburgh, vol. xxxiv.

Last summer the Low Level Observatory was equipped by the Meteorological Council with a complete set of self-recording instruments, and the regular observing work began on July 14; and it is intimated that the discussion of the hourly observations made at the top and bottom of the mountain in their bearing on many of the more important meteorological inquiries has been commenced. As intimated in NATURE of February 26 (p. 397), a first instalment of this work is completed, showing the influence of high winds on the barometer at the Observatory on the top of the Ben.

The report summarizes the results in diurnal, monthly, and annual means of temperature, humidity, pressure, wind-force, rainfall, cloud, and sunshine. The latter part of the report deals with miscellaneous observations and discussions, which have been carried on, mostly of a novel character, for which Ben Nevis offers exceptional facilities.

The mean annual temperature of Ben Nevis for these four years is 30°·5, the lowest monthly mean being 23°·2 in March, and the highest 40°·9 in July. The mean annual difference between Ben Nevis and Fort William is 15°·9, the least monthly difference 14°·2 in November, and the greatest 17°·8 in May. These results show the rate of decrease of temperature with height to be 1° for every 275 feet of ascent for the year; the rates are most rapid in April and May, and least rapid in November and December, these being 1° for each 247 feet and 307 feet respectively. From a discussion of the daily maxima and minima it is seen that in winter the decrease of temperature with height is nearly as great during the night as during the day, but from April to September the rate of fall during the day is about a half more than that of the night.

But the rates of decrease from day to day differ widely from these mean values and from each other. The greatest difference between the two Observatories was 28°·1 at 2 p.m. of June 8, 1885. The temperature of the top, however, has frequently stood higher than that of Fort William. The greatest deviation occurred at 8 a.m. of November 18, 1885, when, while the temperature of Fort William was 22°·2, that of the top was 35°·1, or 12°·9 higher. These inversions of temperature are significant phenomena, from their obvious and intimate relations with anticyclones, and their connection with neighbouring cyclones; from the extraordinarily dry states of the air which frequently accompany them; and the unusually high barometer at the top when reduced to sea-level, as compared with the sea-level pressure at Fort William.

The repeated occurrence of excessive droughts is one of the most striking features of the climate of Ben Nevis. On July 30, 1885, there occurred a good example of these droughts, when, from 1 a.m. to 4 a.m., the dew-point fell from 44°·8 to 21°·8. But by far the greatest drought was in March 1886, commencing at 1 a.m. of the 11th, and ending at midnight of the 12th; the mean relative humidity of the first 24 hours was 19, and of the second 15, the lowest being 6 at 8 p.m. of the 12th. Such low dew-points and humidities, frequently marked off sharply from high dew-points and humidities, often occur; and, it may be remarked, their occurrence suggests an explanation of the irregular geographical distribution of those disastrous frosts which occur the following night in some districts, although not at all in districts closely adjoining.

The mean annual pressure at Ben Nevis is 25·300 inches, the lowest monthly mean being 25·106 inches in January, and the highest 25·516 inches in June, the difference thus being 0·410 inch. As compared with the sea-level pressure at Fort William, the mean annual difference is 4·562 inches, the greatest monthly difference 4·626 inches in March, and the least 4·483 inches in July, these being, it need scarcely be added, the months of lowest and highest mean temperature respectively. The difference between the mean monthly maximum and minimum is thus 0·143 inch. For these two months the mean temperatures of the stratum of air between the top and bottom of the mountain are 31°·6 and 49°·0, on the assumption that the mean temperature of the intervening air stratum is the mean of the temperature at the top and bottom. Hence the vertical displacement of the mass of the atmosphere for a temperature difference of 17°·4 is represented by a barometric difference of 0·143 inch. Considering the successful arrangements which have been made to minimize the effects of solar and terrestrial radiation at both the upper and lower Observatories, and their close proximity to each other, this result may be regarded as the most important datum hitherto contributed by meteorology for the discussion of inquiries into the relations of height to temperature and pressure in the free atmosphere.

A table of corrections for height for the barometric observations of the Observatory has been prepared, chiefly empirically, for each degree of air temperature and each tenth of an inch of sea-level pressure. With the two sea-level pressures of the upper and lower Observatories thus obtained, various questions may be investigated, such as the effect of high winds on the barometer; the varying relations of pressure and temperature to anticyclones, cyclones, and particularly the regions in front or rear of cyclones; and the relation of pressure to heavy falls of rain.

For the period dealt with, the mean annual amounts of rainfall at the top and bottom are 129·47 inches and 77·33 inches, or about a half more at the Observatory than at Fort William. The observations show that on Ben Nevis, one day in from three to four days has been without rain; and that in one day out of nine, 1 inch of rain, or upwards, has been collected. The time of the year when the great annual fall of temperature takes place is coincident with the time of heaviest rainfall; and the time of least rainfall with the time of the greatest increase of temperature.

The mean minimum temperature of the day occurs from 5 to 6 a.m., and the maximum from 1 to 3 p.m., according to season, the daily range in winter being only 0°·8, and in summer 3°·5. The great daily variations of temperature observed on Ben Nevis are not due to the sun, but they are the temperatures which accompany the cyclones and anticyclones as they successively appear and disappear. The great importance of the hygrometric observations lies in the part they play in the occurrence of daily changes of weather attendant on these cyclones and anticyclones; and in investigating these relations, it is not mean humidities, but the individual observations which are so valuable.

In all seasons, the barometric curves show the double maximum and minimum pressure. Their times of occurrence are, first minimum from 5 to 6 a.m.; first maximum from 11 a.m. to 2 p.m., second minimum 3 to 7 p.m.; and second maximum 8 to 9 p.m., according to season. Like all high level Observatories situated on peaks, the largest of the variations from the daily mean is the morning minimum, and the least, the afternoon minimum, the former being 0·016 inch below the mean, and the latter 0·001 inch above it, on the mean of the year. The relatively large minima in the early morning is due to the cooling of the atmosphere during the night, by which the air contracting sinks to a lower level, thus lowering pressure at high levels, and, consequently, this effect is greatest in the summer months when the diurnal range of temperature is at the maximum. The expansion of the air from the increase of temperature during the day raises its mass to a higher level, thus maintaining the barometer at a higher point during the time of the afternoon minimum.

The maximum velocity of the wind occurs during the night, and the minimum during the day, in all months of the year. This peculiarity in the diurnal variation, being just the reverse of what obtains at low levels, is explained by the circumstance that during the night cold currents of air descend the slopes of the mountain on all hands, and the air currents from higher levels which take their place bring with them their higher velocities. On the other hand, during the day, air currents ascend the slopes of the mountain, carrying with them to the summit their velocities diminished from various causes during the ascent. One effect of these ascending currents carrying with them the higher humidities of lower levels, is illustrated by the partition during the day of the sunshine. Thus, in the nine months of spring, summer, and autumn, there are 306 hours of sunshine before noon, but only 285 hours after it.

The concluding portion of the report deals with the miscellaneous discussions and investigations on the formation of snow crystals, winds and rainfall, diurnal variation of wind direction, the thermal wind-rose, rain-band observations, St. Elmo's fire, thunderstorms, mean temperature of each day in year, hygrometry, optical phenomena, and earth currents in the telegraph cable; but as the results of these have from time to time appeared in NATURE, further reference to them is unnecessary.

We would draw special attention to the Observatory log-book, pp. 316–56, which is a remarkably readable, as well as an instructive, document. The following extract presents an interesting side of the Observatory work in this isolated and exposed situation:—

"*January* 26, 1884.—In forenoon wind backed from south to south-east and blew hard. As the drift made it impossible to read thermometer at 1 p.m., Mr. Omond and Mr. Rankin went out tied together, but found it impossible to go farther than the end of the snow porch with safety; at 4 p.m. they got as far as the box, but could not see instruments as the drift blew up in their faces. No temperature observations were taken till 10 p.m., when wind moderated and observations were resumed. There was thus a gap in the temperature observations from noon to 9 p.m. inclusive. Quarter and half hourly barometer observations were taken in afternoon. Lowest recorder reading (corrected to 32°) 23·173 inches."

Optical phenomena, including after-glows, halos, mock suns, mock moons, glories, &c., have been fully observed, and the results are in many respects of the greatest interest. The following graphic account of St. Elmo's fire will be read with interest:—

"*October* 29, 1887.—At 1h. 5m. a.m. St. Elmo's fire was seen in jets 3 to 4 inches long on every point on the top of the tower and on the top of the kitchen chimney. Owing to the number of jets on each cup of anemometer, the instrument was quite ablaze. On the kitchen chimney the jets on the top of the cowl were vertical, and those on the lower edge of same horizontal. The fizzing noise from the different places was very distinct. While standing on office roof watching the display, the observer felt an electric sensation at his temples, and the second assistant observed that his (the observer's) hair was glowing. While standing erect the sensation and glow lasted, but on bending down they always passed off. On raising the snow-axe a little above his head, a jet 2 to 3 inches long shot out at the top. At 1h. 15m. a.m. the fire vanished from every place at the same instant. A shower of snow and snow-hail (conical) was falling at the time, and the wind was variable south to south-west breeze—very flawy."

THE PHOTOGRAPHIC CHART OF THE HEAVENS.

THE Permanent International Committee for the prosecution of the photographic chart of the heavens, has met, deliberated, and adjourned. It will be generally admitted, when the result of their discussions has been digested, that the promise of much good work has been given, and the accomplishment of a photographic chart been brought nearer within the scope of practical astronomy. At a future opportunity we hope to give in some little detail an outline of the arguments that have succeeded in causing deviations from the plan originally contemplated. Now, we can only give a brief account of the report of Admiral Mouchez, and a summary of the more important results which have received the support of the Committee.

Admiral Mouchez's report may be considered as divided into three parts: first, that relating to the installation of the photographic instruments; second, to the methods and apparatus necessary for the measurement of the negatives; and third, the manufacture and employment of *réseaux*. From the first of these sections we learn that all the participating Observatories are provided with satisfactory telescopes; but, unfortunately, the grave political events which have disturbed the Chilian Government are likely to operate adversely on the scientific advance of that country, and the station at Santiago may possibly have to be abandoned, M. Maturana, the Chilian astronomer, having received orders to report himself to his Government for military service. Some delay has been occasioned at Rio de Janeiro by the removal of the Observatory to a distance of six or eight kilometres, where, under more favourable atmospheric conditions, the photographic equatorial is being erected. With these exceptions, the Observatories declare themselves all ready for work.

With regard to the second section, we learn that the construction of the measuring instrument, generously offered by M. Bischoffsheim, has been delayed, owing to difficulties of correspondence between MM. Gill and Kapteyn; but now that these gentlemen have had an opportunity of deciding the particular form the instrument should take, it will be rapidly proceeded with, and it is believed that the employment of such an instrument will greatly abridge the difficulties of measurement and calculation.

The manufacture of the *reseaux* has been definitely abandoned by the authorities at Berlin, but M. Gautier has constructed an instrument for the ruling of these necessary adjuncts, and he is now in a position to supply those Observatories which have failed to obtain *réseaux* from M. Vogel.

Three important points have been before the Committee, and it has been found necessary on these points to modify the decisions of previous Committees. The first of these referred to the desirability of obtaining on the plates of shorter exposure, destined to form a catalogue, impressions of star images with one-fourth of the exposure found necessary to secure the impression of an eleventh magnitude star. The result of this decision would have been to give a picture of the heavens obtained with an exposure of a minute and a half, or a minute, or even less. This project has now been abandoned in favour of one arranged to give impressions, very feeble in character, of stars of the eleventh magnitude, while on the same plate will be exhibited a picture of the heavens obtained with an exposure of twice the length necessary for producing star images in the former case. Thus we may expect on these catalogue plates, exposures of three to four minutes, and also of six to eight minutes.

Another interesting point, over which excitement waxed keen, arose on a proposal of M. Henry to substitute three exposures of equal length, arranged at the